Volume 38 April, 1952 *Number 4*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

THE AVIATION INDUSTRY

TEXACO

Faithfully yours for Fifty Years
1902 1952

WINGED PROGRESS

The Age of Flight began at Kitty Hawk, N. C., on December 17, 1903 . . . and the aviation industry, with which Texaco has been so long and so intimately associated, came into being shortly thereafter.

Following up its activities in the early "wood and wire" days of aviation, The Texas Company, in 1927, hired Captain Frank Hawks as Superintendent of its Aviation Division. Over the next several years, Captain Hawks, flying various Texaco-owned aircraft, set many transcontinental and other speed records and visited by air the major cities of the United States, Latin America and Europe . . . building public acceptance for the idea of commercial aviation.

At the same time, these Texaco aircraft served as "flying laboratories," testing the aviation fuels and lubricants developed by Texaco research and produced in Texaco refineries. Texaco was, for example, one of the leaders in developing commercial production of 100 octane fuels . . . and head-and-shoulders above the crowd in lubricants to meet the requirements of advanced aircraft engine design.

As a result of this progressive pioneering, Texaco is today acknowledged leader in the field of aviation. In fact –

For over 15 years, more revenue airline miles in the United States have been flown with Texaco Aircraft Engine Oil than with any other brand.

And Texaco aviation research still goes on. As supersonic speeds create a need for new fuels and new lubricants, the aviation industry will find that Texaco, as always, has them ready!

THE TEXAS COMPANY

Faithfully yours 50 for Fifty Years

LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

Published by

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THE AVIATION INDUSTRY

THROUGHOUT the first half century of heavier than-air flight, now rapidly drawing to a close, aviation probably has utilized more basic sciences and more mechanical techniques than any other industry. Today a responsible employee in the aircraft manufacturing or air transport industry is required to know not only something of aerodynamics but also of aerology, aero-elasticity, combustion, electronics, geography, heat transfer, meteorology, hydraulics, metallurgy, physiology, photography, thermodynamics, and pneumatics. All of this, of course, is in addition to the basic sciences — mathematics, physics, mechanics, and chemistry.

As one of the industries that has been closely allied with the aviation industry, the petroleum industry is proud of the part that its products and technical advances have served in the growth and development of aviation. Powered flight depended on the gasoline motor from its first beginning at Kitty Hawk. Petroleum lubricants have had just as prominent a role in the lubrication of engines and of airplane components. Let us turn for a moment and look back over the accomplishments made in aviation during the last fifty years, the same period that has seen the phenomenal growth of our automotive and petroleum industries.

BACKGROUND

Fifty years ago, in 1902, all over the world men were active in many places — scientific laboratories, back-yard barns, or isolated shops — racing to accomplish the long-sought objective of sustained flight with a machine heavier than air. It need not be emphasized, though, how the race was won in 1903 by the immortal Wright brothers; quiet, painstaking, developing and proving new aerodynamic theory as they went along.[1] The story is also familiar of how, lacking a suitable low-weight engine with sufficient power to propel their machine, the Wrights designed and built their own engine, despite expert assurances that "it couldn't be done."

The aircraft types proposed or even built experimentally from 1903 to 1912 encompassed virtually every configuration that later became popular — pusher, tractor, canard, biplane, triplane, multiplane, monoplane — high, mid, and low wing, barrel-wing, autogyros, helicopters — every conceivable form of fixed and rotary wing aircraft.

Unfortunately, many of these developments came to an early end, often because the capital, basic research, materials, or manufacturing techniques were lacking to make them feasible at the time. Nevertheless by 1912-14, the heavier-than-air flying machine had become established to the point where it was capable of flying distances of up to 200 miles at speeds of more than 60 miles per hour. World War I found a use for such machines, and gave tremendous impetus to efforts to advance their performance. By the 1918 Armistice, a multiplicity of aircraft types were further developed, mainly for military uses, but having features or elements which were later to prove of value in commercial aviation. Some of these, such as the turbosupercharger, may not have reached transport service until thirty years

1 Numbers refer to references at end of article.

after the first military applications, but the military heritage was present, nevertheless.

Soon there followed the inception of the U. S. Government Air Mail Service in 1919, using mostly converted DH-4's with Liberty engines. Point-to-point passenger air services sprang up over the world, giving incentive to the development of reliable, fast, closed-cabin airliners. With the passage of the Air Mail Act of 1926, turning mail service over to contract operators, the present air transport industry was born in the United States, providing a commercial outlet for the aviation manufacturing industry. Incentive for the development of fast, high performance airplanes, with more and more powerful engines was furnished by the National Air Races and the International Schneider Cup Races.

Many volumes would be needed to tell the story of the rapidly growing aviation industry from 1926 to the present and to give credit to the men and firms who contributed to this growth. Statistics present the picture better than words, as in Table I. Thus, late 1941 saw 350 twin-engine transports in scheduled service in the United States, along with the Boeing Model 307 pressurized cabin Strato-liner and Model 314 four-engine flying boats, with deliveries of the four-engine Douglas DC-4 and Lockheed Constellation imminent.

New highs in reliability, passenger load factors, and aircraft utilization were set during the wartime years. Beginning in late 1945, though, the wartime impedance to airline growth was quickly erased and today the scheduled trunk lines are in the most favorable position of their history, physically and financially. Certificated freight carriers, and charter and non-scheduled services have benefited from the same trends in the post war period, many of them contributing invaluably to the Berlin and Korean air-lifts, along with units diverted from the scheduled carriers. The growth and strengthening of U. S. international air carriers is well known to all readers, providing daily schedules to all parts of the free world in fast, comfortable over-weather aircraft such as the Constellation, DC-6, and Stratocruiser. Local service airlines have been created, bringing essential and contributive service to larger and smaller cities throughout the entire country.

While today's vast air transportation system has been taking shape, progress in military aircraft has been equally notable. Year after year has marked the development of faster and faster machines, with

Courtesy Institute of Aeronautical Sciences

Figure 1 — There was little need for today's high performance aircraft fuels and lubricants for the machine shown in this pioneer photograph.

TABLE I

Growth of Scheduled U. S. Domestic Airlines, 1926-51

Year	*Number of Operators*	*Number of Aircraft*	*Passenger Miles Flown Millions*	*Passengers Carried Millions*	*Mail Ton-Miles Flown Millions*
1926	13	100*	1.3*	5,782**	N.A.
1931	39	490	106	0.47	N.A.
1936	24	280	436	1.02	5.74
1941	19	370	1,492	3.85	13.12
1946	24	674	6,068	11.89	32.95
1947	28	810	6,313	12.28	33.09
1948	31	878	6,245	12.32	37.93
1949	37	913	7,065	14.02	41.42
1950	38	960	8,351	16.17	47.01
1951	36	993	12,089*	22.44*	64.47*

*Estimated
**Actual Number
Data from CAA Statistical Handbook of Civil Aviation, and Industry Sources.

greater armament and range, to provide victory in total war and security against aggression. Today the swing is to jet propulsion, though piston engined aircraft still serve in many capacities in our over-all air power. Rocket powered research craft exceed the speed of sound, and electronically controlled guided missiles are being groomed for aerial defense and prevention of aggression without sacrifice of pilots.

Thus, the aviation industry has been formed, mighty in war or threat of war, but now also vast in its peace-time activities — air transport and civil aviation. Like aircraft design, petroleum fuels and lubricants have not remained static throughout the period in reference. Processing developments, new technologies, synthetically reformed or newly created materials have come from the petroleum industry, so that today's modern airplanes are serviced with petroleum products just as up to date as their swept-back wings and roaring after-burners. A summary of some of these significant developments follows:

FUELS AND LUBRICANTS FOR AIRCRAFT POWER PLANTS

At this writing the reciprocating (piston) engine powers the more than 1200 aircraft of the U. S. air carriers, over 89,000 registered civil aircraft, and is unexcelled for maximum range in the greatest inter-continental bombers. It also serves the military in both new and established transports, long-range patrol planes, trainers, liaison planes, and not-yet-obsolete light bombers and fighter bombers. Much of the present position of the piston engine is due to its high octane fuels, the mutual contribution of the engine builders and fuel suppliers.

Paralleling the development of more efficient aircraft and engines, the use of better fuels permitted a reduction in fuel cost per ton-mile, despite general rising costs and the decline in value of the dollar, Table II.

Fuels for Reciprocating Engines

During World War I and the immediate post-war years, increased compression ratio and the desire for supercharging soon forced a need for aircraft fuels with higher anti-knock resistance (octane value) than possible with straight-run gasoline. Limited cooling, and the desire to hold cooling drag down, accentuated tendencies toward knock or detonation and pre-ignition, and spurred the search for better fuels. By today's scales, 1918-27 Fighting Grade Aviation Gasoline probably varied in octane from 50 to 65,[2] with distillation kept low to compensate for inadequate manifolding and distribution. With the recognition and study of the problem of gasoline knock in the early 20's, and the development of the octane scale, a solution was soon forthcoming in the form of tetraethyl lead, still unequalled as a knock suppressor when added to gasoline in minute quantities.

But tetraethyl lead alone could increase the octane rating of the best straight run gasolines only to a level of about 87, even in optimum concentrations. Thus, study turned to consideration of the differences in anti-knock value due to type of gasoline or hydrocarbon structure, and methods to synthesize the most desirable type. These efforts led, in 1934, to production of the first large batch of iso-octane, or 100 octane fuel. Test and service results with the new fuel were outstanding.[3] There soon followed the now famous "Alkylation" process, which melds two light petroleum gases to form a mixture of high-octane hydrocarbons in the boiling range of aviation gasoline. This product, known as alkylate, and produced by one of several

TABLE II

Fuel Costs and Total Direct Operating Costs — Transport Aircraft

	Fuel Costs, Cents		*Total Direct Operating Costs, Cents*	
Aircraft Type	*Per Mile*	*Per Ton-Mile*	*Per Mile*	*Per Ton-Mile*
DH-4 (1921)	2.6	8.7	26.4	88.7
Boeing 40 (1926)	3.0	5.0	20.2	33.7
Ford Tri-Motor (1926)	6.1	3.8	34.1	21.3
Lockheed Vega (1929)	1.7	2.5	15.1	22.4
Boeing 247 (1933)	3.6	2.6	21.1	15.1
Douglas DC-3 (1936)	5.9	2.4	26.7	10.7
Douglas DC-4 (1945)	13.9	2.0	52.6	7.5
Douglas DC-6 (1951)	24.5	1.8	83.5	6.0

Data through DC-3 from "Technical Development and Its Effect on Air Transportation," E. P. Warner, James Jackson Cabot Lecture, Norwich University, 1938. Remainder from calculations based on industry sources. All costs in contemporary dollar values for the period given.

TABLE III

Aviation Gasoline Characteristics — World War I vs. World War II

	World War I[1]	*World War II*[2]
Octane Rating	50 to 65[3]	100/130[4]
Distillation, °F.		
5 per cent	140 Min., 158 Max.	(RVP 7 psi., Max.)
10 per cent	——	167 Max.
50 per cent	203 Max.	221 Max.
90 per cent	235 Max.	284 Max.
End Point	284 Max.	356 Max.

[1] Specifications adopted by Committee on Standardization of Petroleum Specifications, October 2, 1918, for Fighting Grade Aviation Gasoline.
[2] Specification AN-F-28 and predecessors.
[3] Estimate, not covered by specifications at the time.
[4] 100 Octane Number Lean, 130 Performance Number Rich.

alkylation processes, is the basic high octane component of our present military and commercial aviation gasolines.

Concurrent advances in supercharger design, high octane fuels, and engines permitted the use of very high manifold pressures for take-off and combat power. At these high powers, it was found that mixture enrichment, beyond even best power mixture, permitted further increases in manifold pressure and consequently still more power up to the point that a cooling, structural, or knocking limit was reached in the engine. But the anti-knock value of the fuel was determined by the existing test methods only at lean fuel-air ratios, corresponding to cruise power settings. Thus the need was recognized, first by the British and shortly thereafter in this country, for control of the rich mixture anti-knock characteristics of gasolines under supercharged conditions.

This need was met by the petroleum industry by development of a laboratory test method to control rich mixture properties and by incorporation of blending agents into aviation gasoline to insure the required level of rich mixture performance. These rich mixture blending agents, notably the class of hydrocarbons known as aromatics — benzol, toluol, and derivatives — also served to extend the critical supply of high octane base stocks, aviation alkylate, without which the tremendous wartime requirements for aviation gasoline could not have been met.

The rich mixture octane test method, developed cooperatively under Coordinating Research Council sponsorship, was known first as the AFD (Aviation Fuels Division) 3-C and later as the CRC-F-4* method. This method rates fuels at variable supercharge on a basis of the knock-limited power permissible at controlled fuel-air ratios.

*Now ASTM Designation D 909.

Correlation of laboratory and full-scale engine knock rating data permitted development of the "Performance Number" scale, in which fuel ratings are expressed in terms of the power developed on the fuel at knock-limited conditions versus the power obtained on iso-octane or 100 octane. Iso-octane, then, has a value of 100 Performance Number (P.N.) and a rating of 150 P.N. for a fuel means that under standard conditions 150% as much power may be developed on this fuel as on iso-octane.

In the present fuel rating and grade designation system — Grades 80/87, 100/130, 115/145, etc. — the first number is the Lean Octane Rating and the second the Rich Rating. For both Lean and Rich Ratings in grade designations, Octane Number is used for values below 100 and Performance Number for values above 100.

Grade 115/145 Aviation Gasoline is presently used in all combat military aircraft and will be required in some new airliners such as the Lockheed Super Constellation L-1049. From 4.0 to 4.6 ml. of TEL per gallon are found necessary to produce 115/145 ratings with even the best components. To alleviate lead deposition and spark plug fouling difficulties in some engines in commercial service, it has been possible to rerate certain engines with no loss of power on 108/135 fuel containing 3.0 ml. of tetraethyl lead per gallon. Since no loss of fuel production is involved, that is Grade 108/135 contains the same proportion of short-supply high octane ingredients as Grade 115/145 but merely less TEL, current government regulations permit the continued manufacture of Grade 108/135 with 3.0 ml. of tetraethyl lead, although other grades are temporarily held to 4.0 ml. per gallon minimum to increase production.

All grades of aviation gasoline currently possess both lean and rich mixture octane control, namely,

80/87, 91/98, 100/130, etc., insuring the desired anti-knock quality at all conditions of operation. Research is continuing on development of improved fuel rating methods and utilization of optimum composition for high octane military gasolines. It may be anticipated that benefits from this work eventually will be reflected in improvements in the quality of aviation gasolines for commercial use, where the life of the piston engine has no foreseeable end.

Oils for Reciprocating Engines

LUBRICATION for October, 1951 contained a current summary of oils for aircraft reciprocating engines. It was shown that high standards of reliability and performance, beyond even the goals of a few years ago, have been achieved with the present highly refined straight mineral oils.

These oils were evolved only after the shortcomings of castor oil became evident; oiliness agents also were short-lived as a lasting solution to engine wear or scuffing problems. Accordingly, designers turned more and more to the permanent solution of improved materials, surface finishes, and strengthened designs, rather than "trick" oils. Oil refiners contributed through constant improvement of mineral oils — selection of crudes, closer control, de-waxing for lower pour points. Solvent refining was introduced to remove impurities and the least desirable components while retaining the most desirable naturally occurring constituents, permitting the production of stable, high quality oils of high Viscosity Index.

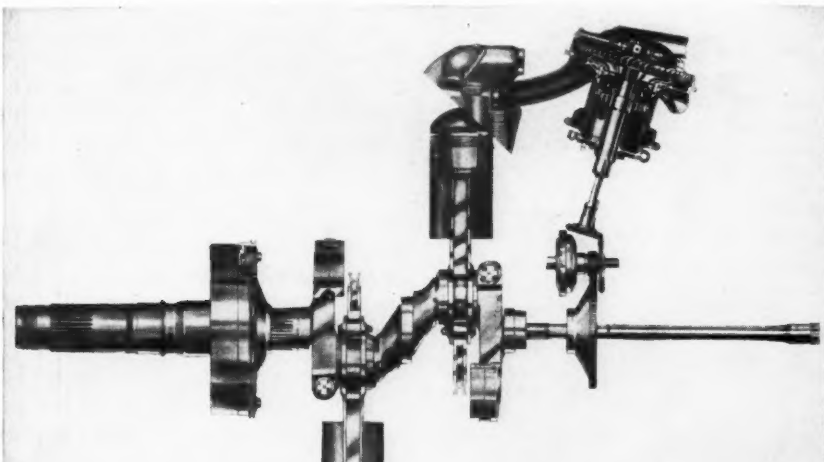
The October 1951 issue relates how the need for oxidation resistance and detergency in modern high duty engines has now focused attention on the development of additive aircraft engine oils. The air worthiness of some of the new additive oils has now been established. Service testing to evaluate the benefits of additive oils continues. These benefits have been significant in other fields;* their realization in aviation is considered only a matter of time and definition of the right oils to do the job.

A progress report on service evaluation of additive oils may be covered briefly by stating that one or more oils used in service to date afford substantial reductions in high temperature engine deposits. Benefits are reflected in increased parts life and longer periods between overhaul. The objectives of additive oil development, and the benefits to be derived, may be summarized as to enhance the performance of the best straight mineral oil by:

1. Imparting over-all engine cleanliness.
2. Providing high resistance to oxidation.
3. Retarding engine wear.
4. Reducing valve stem and guide deposits.
5. Keeping rings free.
6. Improving lubrication of bearings and gears.

Each of these objectives contributes to engine reliability and durability as influenced by oil quality. Realization of the possibilities of improved oils and utilization of their best features requires co-

*LUBRICATION, January, 1952, July, 1950, March, 1950, January, 1946.



Courtesy Wright Aeronautical Division Curtiss-Wright Corporation

Figure 2 — Schematic view of the power recovery turbine of the Wright "Turbo-Cyclone" compound aircraft engine.

ordination with engine design and operational factors affecting oil performance. It is here that service evaluation is of greatest importance in order to apply the design benefits of additive oils under actual service conditions.

Detergent oils appear to have been less effective in reducing lead sludge deposits. More promising avenues of approach toward elimination of excessive lead sludges, particularly where limiting to engine overhaul life, appear to be along the following lines, all of which are being investigated by engine builders or operators:*

1. Redesign of engine oil system or passages to eliminate trapping or centrifugal separation of dense sludges.

2. Oil filtration.

3. Modification of the amount or type of lead sludges entering the oil from the combustion chamber, through improved scavenging agents for TEL combustion products.

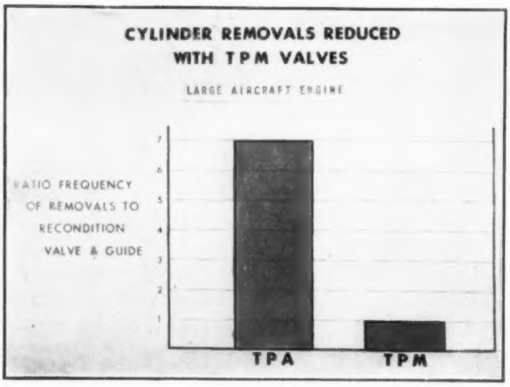
*These projects are discussed more fully in "Aircraft Engine Oils," LUBRICATION, October, 1951.

**"Aircraft Gas Turbine Fuels and Lubricants," LUBRICATION, April, 1948.

	TPA	TPM
ULTIMATE STRENGTH P.S.I.		
ROOM TEMPERATURE	109,500	149,500
1400° F	32,500	66,000
HARDNESS, BRINELL		
ROOM TEMPERATURE	187	266
1400° F.	108	175
LEAD CORROSION GMS/dm²		
1675° F FOR 1 HR	60.5	2.3
STRESS ELONGATION, HRS		
1350° F 15,000 P.S.I. 1%	0.7	
1350° F 30,000 P.S.I. 1%		139.5

Courtesy Thompson Products, Inc.

Figure 3 — Comparison of mechanical properties of TPA and TPM exhaust valve materials. TPM is a new valve material developed to give greater corrosion resistance and higher strength at operating temperatures. Service data below show a comparison of the frequency of premature cylinder removals to recondition valve and guide, using the two materials in large aircraft engines.



AIRCRAFT GAS TURBINES

Only for emphasis need it be repeated that development of the aircraft gas turbine, or jet, engine is universally regarded as the greatest advancement in aircraft propulsion since the first successful propeller driven flight. Functional and structural details of jet engines have been covered in a previous issue, with a discussion of fuel and lubricant requirements as defined at that time.**

Aircraft gas turbine engines may be considered as consisting of four main sections:

1. *An air compressor,* centrifugal or axial-flow type, at the front of the engine, furnishing a large amount of air at moderately high pressures.

2. *A combustor section,* either a number of can-type burners or in some models an annular shroud, wherein fuel is introduced and burned in the compressed air.

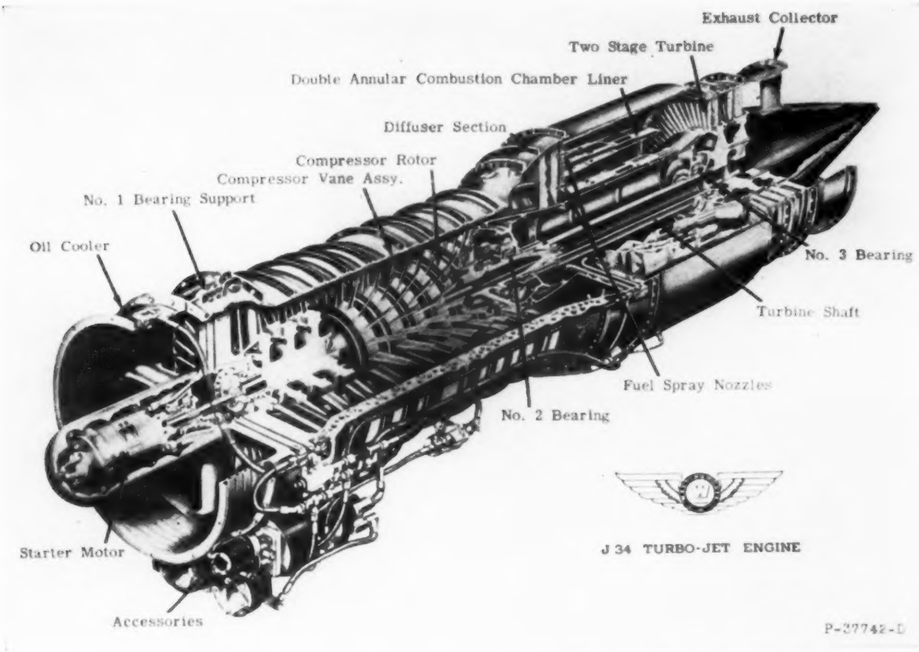
3. *A gas turbine,* driven by the combustion gases and which drives the compressor, to which it is connected.

4. *A tail cone,* or jet nozzle section, in which the turbine exhaust gases expand rearward to furnish jet propulsion.

Simple jet engines made up of these four elements and the necessary accessories, and in which the total propulsion is derived from the jet exhaust are commonly called "turbo-jet" engines. In other designs, power is also extracted from one or more turbine stages to drive a propeller on the front of the engine; such engines are called "turbo-prop," or less frequently "prop-jet," engines. Since the turbine shaft speeds are in the range of 6,000-12,000 rpm, an inefficient range for present propellers, the propeller is driven through reduction gearing, usually of between 8 and 12:1 ratio.

Following the pattern predicted soon after the close of the fighting in World War II, all new U. S. fighter and high speed aircraft are powered by turbo-jet engines. High speed, high altitude jet bombers are also being produced, with even larger models under security classification. Jet transports are not as far along, though British operators are flight testing both turbo-jet and turbo-prop powered transports in simulated routine airline service. Extensive study is being given to jet transport development by government, military, manufacturing, and airline experts, however.

Consensus of views of industry experts is that the next step, completely new turbo-jet airliners of much higher speed, is inevitable; but considerable difference of opinion exists as to when such developments should be timed. The following quote (Conclusion 10) from the recent report of the Foreign Survey Group of the Prototype Aircraft



Courtesy Westinghouse Electric Corporation

Figure 4 — Cut-away view of the Westinghouse J-34 turbo-jet engine, with identification of components.

Advisory Committee summarizes the trends in new designs:

"10. Jet transport designs started now will operate at speeds up to 550-600 mph. just below the transonic range and the speed of sound, and should remain basically unchanged for some time to come, since the next speed increase will be to a definitely supersonic regime, 900 mph. and up, with many fundamental differences in design and propulsion. Hence, equipment now being designed and soon to be built should have a long period of use before obsolescence."

Aircraft Gas Turbine Fuels

Aircraft gas turbine fuel quality requirements are principally affected by two sets of factors:

1. Requirements of the engine, dictated by such considerations as combustion characteristics, efficiency, and metering considerations.

2. Requirements of the aircraft and environment and the aircraft fuel system external of the engine proper.

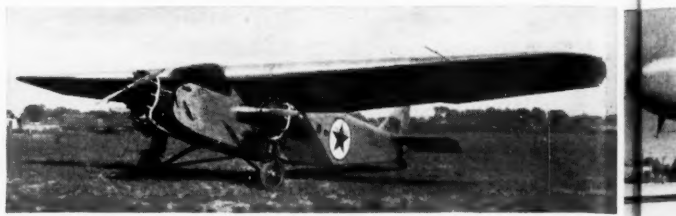
Initial turbine development and operation was conducted with ordinary kerosene type fuels. In Great Britain, a freezing point requirement of —40° F. has been used for the kerosene type fuel; however, U. S. specifications were written at —67° F. freezing point, possibly with Arctic handling and ground considerations in mind. Jet aircraft endurance and fuel cooling rates in aircraft tanks are presently such that the —40° F. freezing point does not appear to offer any deterrent to flight use, although outside air temperatures at operating altitudes may be much lower.

The kerosene type fuel for military use is known as Grade JP-1, described by Specification MIL-F-5616.* The potential availability of this type fuel is severely limited; therefore attention turned to fuels of wider boiling range.** The first proposal studied, a low vapor pressure gasoline known as Grade JP-2, former Specification AN-F-34, also suffered from availability limitations, hence a very wide boiling range fuel, 100 to 600° F., and 5-7 psi Reid Vapor Pressure, was introduced. The wide boiling range fuel, containing gasoline, kerosene, and light Diesel fuel fractions is Grade JP-3***, now part of Specification MIL-F-5624A. While engine operational characteristics of JP-3 were found adequate, research studies and service experience with this type fuel disclosed that the high vapor pressure presented serious problems in jet aircraft operation, chiefly fuel boiling with high evaporation and slugging losses under conditions of rapid climb, although there were also fuel pumping and system problems.

Consequently, a low vapor pressure, 2-3 psi R.V.P., version of wide boiling range fuel has been

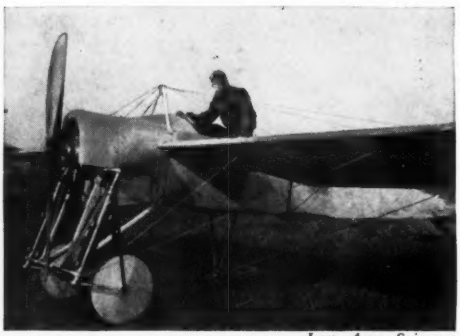
*Formerly AN-F-32.
**LUBRICATION, April, 1948.
***Formerly AN-F-58 and 58a.


Inst. Aero. Sciences
Boeing 40-B-4


Ford Tri-Motor

United Air Lines
DeHavilland DH-4


Lockheed Vega (Left) cLockhee

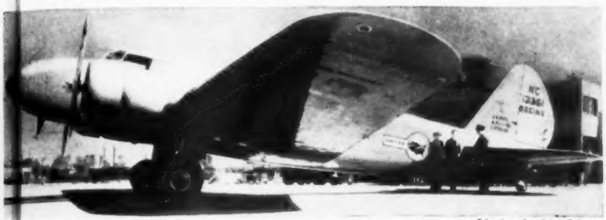

Inst. Aero. Sciences
Moisant Monoplane "Blue Bird"


United Air Lines
Wright Bi-plane

FIFTY YEARS OF AIRAFT

	High Performance						
Year	*1903*	*1912*	*1922*	*1932*	*1942*	*19*	*1922*
Example	Wright Bi-plane	Curtiss Hydro-plane	Curtiss Racer	North-rop Gamma	NAA P-51	N F	Marti MB-
Type	1 place "Kitty Hawk" (Reference 1)	2 place Flying Boat	1 place Bi-plane	1 place Metal Mono-plane	1 place Fighter	1 p J Fig	2-eng Bi-plane
Wing Span, Feet	40	38	19	48	37	3	74
Length, Feet	20	41	19	30	32	3	43
Gross Weight, Lbs	745	1,700	1,950	7,000	10,000	16,5	12,07
Useful Load, Lbs	160	500	496	3,500	3,000	N.	5,000
Total Power, BHP	12–16	80	400	710	1,590	5,20	840
Power Loading, Lbs/HP	62	21.3	4.88	10.0	6.29	3.1	14.30
Wing Loading, Lbs/Ft^2	1.5	4.0	14.1	19.3	42.4	60	10.7
Maximum Speed, MPH	30	60	224	248	460	67	107
Normal Cruising Speed, MPH	30	55	70[2]	191	N.A.	N.	60
Normal Range, Miles	∠1	120[1]	N.A.	2,500	2,000	1,2	500

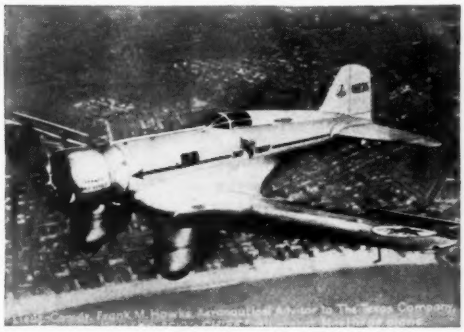
NOTES: Data from Janes' "All The World's Aircraft", 1909–52, and Industry Sourc aircraft cl than one modification exists, data cited for model in service during the y indicated for example only. [1]Estimated. [2]Minimum. [3]Static jet thrust, eq HP, at



Boeing 247 *United Air Lines*

Lockheed Photo
Lockheed Orion

(Left) c Lockheed Air Express



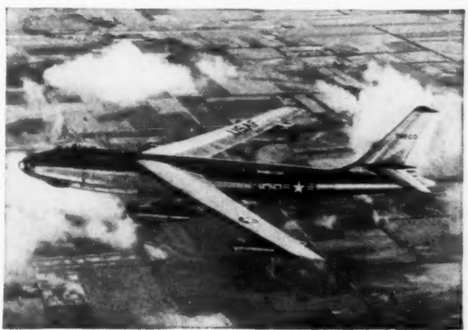
Northrop Gamma

AIRAFT DEVELOPMENT

	Military Bombardment				*Commercial Transport*			
19	*1922*	*1932*	*1942*	*1952*	*1922*	*1932*	*1942*	*1952*
N F	Martin MB-2	Boeing B-9	Convair B-24	Boeing B-47	DH 34	Boeing 247	Douglas DC-4	Lockheed L-1049
1 p J Fig	2-eng. Bi-plane	2-eng. Mono-plane	4-eng. Mono-plane	6-Jet Swept-wing Mono plane	10 place Closed-cabin, Single engine	10 place All Metal 2-engine	44 place 4-engine	92 place 4-engine
3	74	76	110	116	51	74	117	123
3	43	51	67	108	39	51	92	113
16,5	12,075	14,300	62,000	over 185,000	6,200	13,100	65,000	120,000
N.	5,000	5,400	28,000	N.A.	2,000	4,750	30,000	45,000
5,20	840	1,200	4,800	31,200 lb.[3]	450	1,100	5,400	10.000
3.1	14.30	11.93	12.92	5.93[4]	13.75	11.91	12.0	12.0
60	10.7	15.0	59.1	N.A.	10.5	15.6	35.6	72.7
67	107	186	297	over 600	115[1]	182	265	over 350
N.	60	120–150[1]	240	N.A.	105	171	242	330
1,2	500	900–1,000	1,540	over 2,000	365	550	3,000	3,000

y Source aircraft classified according to type after 1922 to permit comparison. Where more
g the yindicated. LUBRICATION holds no brief for models chosen, which are cited
ust, equiv. HP. at 375 mph. [4]Lbs. per lb. static jet thrust. N. A.—not available.

TWA Photo
Douglas DC-2

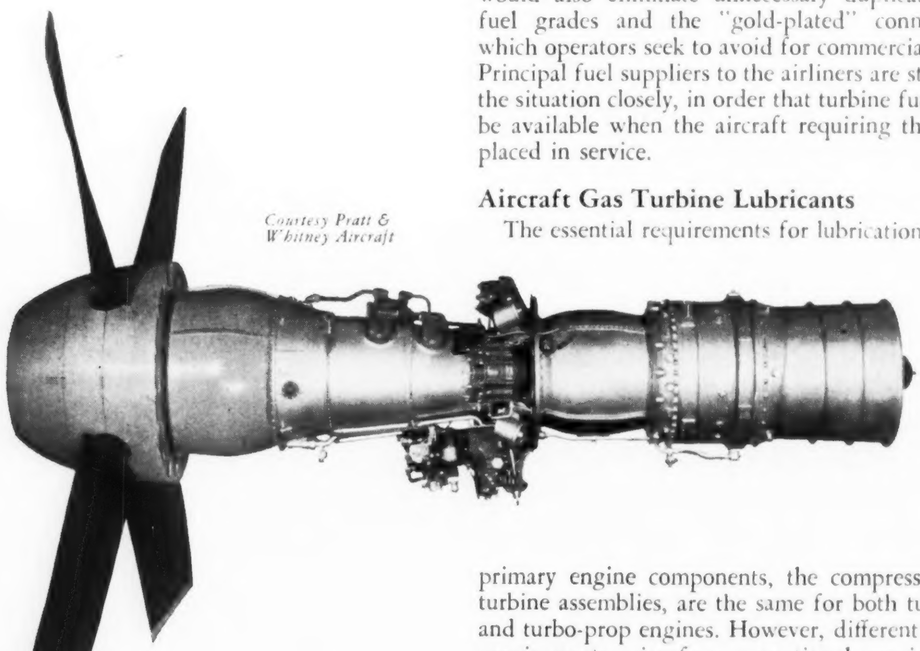


Boeing Airplane Company
Boeing B-47

introduced, including all of the materials contained in JP-3 except the most volatile fractions. Such a fuel is described by Grade JP-4 of Specification MIL-F-5624A. Detail modifications may be made in this fuel as a result of operational experience; however, it now appears that Grade JP-4 meets the essential requirements of jet engine and aircraft operation and will be the preferred type of fuel for maximum emergency production. Engine development and military service activities currently are being switched to this type of fuel.

Although the gas turbine has been shown to be somewhat less exacting in its fuel requirements than the piston engine, it still is not true that the turbine engine, especially in aircraft usage, has a universal appetite. Combustor and nozzle design, as well as fuel metering system operation, are sensitive to fuel characteristics for optimum performance. Many research studies are active in this field, both government-sponsored and private, to the end of obtaining best utilization of available fuel production.[4] Among the items being investigated are the effects of fuel composition on:

1. Combustion efficiency.
2. Carbon deposition.
3. Turbine life or blade erosion.
4. Fuel handling characteristics in aircraft fuel systems.
5. Fuel filtration characteristics, at high and low temperatures, including ice formation.
6. Storage stability.



Courtesy Pratt & Whitney Aircraft

Figure 5 — The Pratt & Whitney Aircraft T-34 "Turbo-Wasp" turbo-prop engine.

Commercial Jet Fuels

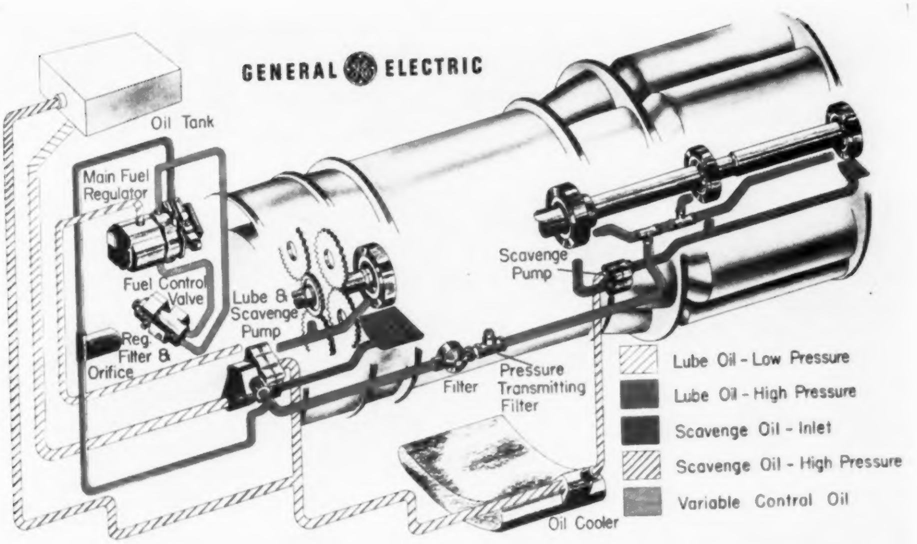
Considerable attention is being given to fuel requirements for commercial aircraft gas turbine fuels. A recent paper summarizes the essential requirements in the eyes of airline operators as:[5]

"1. Low cost per gallon.
2. High B.T.U. content per gallon.
3. Low flammability for safety.
4. Low volatility for fuel economy.
5. Availability.
6. Performance dependability."

The same discussion urges that every effort be made to avoid development of "gold-plated" fuels of the special product class, and consequently high cost. While commercial jet aircraft operation is still some time away, following the normal development pattern the first turbine engines in commercial use will probably be adaptations of military engines, most likely those in existence now. Thus arguments exist for use of the type fuels on which the engines were developed and on which operational experience has been obtained; such a move would also eliminate unnecessary duplication of fuel grades and the "gold-plated" connotation which operators seek to avoid for commercial fuels. Principal fuel suppliers to the airliners are studying the situation closely, in order that turbine fuels will be available when the aircraft requiring them are placed in service.

Aircraft Gas Turbine Lubricants

The essential requirements for lubrication of the primary engine components, the compressor and turbine assemblies, are the same for both turbo-jet and turbo-prop engines. However, different sets of requirements arise from operational requirements of the engines and from the necessity for lubricating the propeller reduction gearing of the turbo-prop engine.



Courtesy General Electric Company

Figure 6 — Lubrication system of the General Electric J-47 turbo-jet engine.

Turbo-Jet Engines

Lubrication of the first service models of turbo-jet engines has been satisfactorily accomplished with light mineral oils such as are described by Grade 1010 of Specification AN-O-6081.* These oils have a minimum viscosity of 10 centistokes (58.8 Saybolt Universal Seconds) at 100° F., a Pour of −70° F. or lower, and Flash Point, minimum, of 270° F. A lighter grade of mineral oil, Grade 1005, with a minimum viscosity of 5 centistokes at 100° F. and improved low temperature properties, has also been developed, principally for the General Electric Model J-47 turbo-jet. In addition to fighter installations, this engine is used in multi-jet bombers where it is desired to shut down one or more engines for cruise fuel economy and range. Subsequent restarting at very low ambient temperatures, −65° F. to −100° F. at operational altitudes, requires an oil possessing fluidity at these temperatures for immediate lubrication and protection of engine and accessory bearings. Grade 1005 also has been used in other engines as demanded by operational requirements.

Turbine bearings normally are cooled by oil and by bleed air from the compressor. The advent of new engine models with higher compressor pressure ratios results in bleed air temperatures considerably higher than found on earlier engines. Bearing development also has progressed to permit higher operating temperatures. Thus bearing lubrication becomes critical with low viscosity mineral oils at these high temperatures. It has not been possible to meet the opposing demands of low viscosity for low-temperature starting and maintenance of viscosity at high temperatures (functions of Viscosity Index) with mineral oils. High evaporation characteristics of the light petroleum oils at temperatures of 350° F. and 400° F. also make them unsuitable. In addition, the flash points of mineral oils are not desirable for use at these temperatures.

Other desirable properties for turbo-jet lubricants are high and low temperature stability, compatibility with bearing and other engine metals, oxidation resistance, and low deposition tendencies at high temperatures in turbine bearings under "soak back" heat conditions at shut down.

Accordingly, engine manufacturers and the military have called upon the chemical and petroleum industries for tailor-made synthetic lubricants with the required characteristics. Synthetic oils with improved high and low temperature properties have been developed and full-scale tested. A new Specification, MIL-L-7808, covers the synthetic aircraft gas turbine oil, with principal requirements as given in Table IV, p. 48.

Availability in sufficient quantity for emergency needs is an important consideration for the synthetic oils. Many units of the petroleum and chemical industries are actively pursuing the development of suitable synthetics which can be produced in the required amounts.

Turbo-Prop Engines

The synthetic type gas turbine lubricants also have desirable characteristics for use in turbo-prop

*Formerly AN-O-9.

TABLE IV

Comparison of Aircraft Gas Turbine Lubricants

Specification	*MIL-O-6081*		*MIL-L-7808*
	Grade 1010	*Grade 1005*	
Viscosity, Kinematic, cs.			
210° F.	*2.48*	*1.70*	3.0 Min.
100° F.	10.0 Min.	5.0 Min.	11.0 Min.
—40° F.	3,000 Max.	*352*	—
—65° F.	*25,000*	2,600 Max.	13,000 Max.
Pour, °F.	—70 Max.	*Below —75*	—75 Max.
Flash, C.O.C., °F.	270 Min.	225 Min.	385 Min.
Neutralization No.	0.10 Max.	0.10 Max.	0.20 Max.

Stability (no separation) at —65° F. and Corrosion and Oxidation Stability at 250° F. Requirements are Equivalent in Both Specifications.

Italics indicate tests not required by specification. Values shown are typical for qualified products.

engines. Requirements for load-carrying ability in gears and extreme pressure properties are incorporated into the specification to ensure suitability in turbo-prop reduction gears. Most, if not all, of the development testing and flight operation with turbo-prop engines in this country has been with Grade 1065 or Grade 1100 aircraft engine oils, since the Grades 1010 and 1005 jet engine oils do not have the necessary gear load-carrying properties. The petroleum-base turbine oils, Grades 1010 and 1005, probably are satisfactory, however, for compressor, turbine, and accessory bearing lubrication unless limited by the same considerations applying to newer turbo-jet engines. In turbo-prop designs incorporating separately lubricated propeller reduction gearing, consideration has been given to use of Grade 1010 oils in the engine in conjunction with MIL-O-6086 aircraft gear oils or Grade 1100 oils in the gear system. MIL-O-6086 gear oil has also been used in the entire system too, with some success although the compounded gear oil apparently has an undesirable effect on deposits in turbine bearings.

The MIL-L-7808 synthetic oil incorporating good gear lubrication properties presents a solution to this problem. Properly compounded, such oils will carry gear loads equivalent or superior to those of Grade 1100 oils, Figure 7. Thus, lubricants covered by the new specification are required for future military turbo-prop engines in addition to certain new model turbo-jet engines.

Jet Propulsion – Ram Jets and Rockets

Research for ram jets and rockets is largely conducted under security wraps at present. Petroleum products may be expected to play an important role in such developments for reasons of availability, heat content, and other desirable characteristics. Already the technical know-how of the petroleum industry in the fields of combustion, synthesis, heat transfer, chemistry, and fuels handling has been applied to these trans- and supersonic propulsion devices. The large scale military program on both pilot-less and manned aircraft and missiles requires continued research on both fuels and lubricants.

AIRCRAFT AND ACCESSORY LUBRICATION

The need for specialized airframe and accessory lubricants arose with the advent of high performance, high-altitude aircraft employing mechanical, electrical, and hydraulic systems for operation of new equipment or for functions previously performed manually.* Early wood-and-wire airplanes were adequately serviced at a few points with automotive greases or industrial ball and roller bearing lubricants, or else required no lubricant at all due to light loading and large clearances in airframe mechanical components.

Operation of complex new aircraft to increasingly higher altitudes presents problems in lubricant development and application, however, which have been met through a series of aircraft greases and oils designed to fit the new requirements.

Not so long ago an operating temperature range of —65° F. to 300° F. appeared adequate for this

*"Lubrication of Airframe and Engine Accessories," LUBRICATION, April, 1946.

series of lubricants, although not met by any single product for continuous operation. Since then, however, upper air research[6] has shown that minimum temperatures below $-100°$ F. may be expected at 35,000 feet and above, Figure 8. Temperatures in the troposphere and stratosphere regions are known to vary with season and latitude, and minimum air temperatures of $-100°$ F. to $-120°$ F. have been measured in flight. Likewise, the upper operating temperature limit has been extended beyond 300° F. in engine accessories located near jet engine heat.

Another significant trend is the miniaturization of airborne equipment, particularly electrical, resulting in small electric motors and actuators with high equilibrium bearing temperatures. Much of the electrical equipment operates intermittently, with alternate exposure to low ambient temperatures and high operating temperatures.

AIRCRAFT GREASES

Four types of aircraft greases have been developed to meet service requirements for the following applications:

1. Low temperature.
2. General purpose.
3. High temperature.
4. Special application — EP and Graphited.

Low Temperature Greases

The first type of successful low temperature grease was a petroleum-oil base grease with low torque requirements at $-67°$ F. for use in control bearings, pulleys, cranks, and related airframe equipment. Such greases* are still adequate for control system lubrication in many medium altitude aircraft, where excellent service has been obtained from the better greases incorporating shear resistance to prevent "working down" or liquefying in service. Low temperature greases made with very light mineral oils have serious shortcomings at elevated temperatures, however, due to rapid evaporation of the light petroleum base oil, and are not suitable for applications above $+175°$ F.

To overcome this temperature limitation, synthetic base low temperature greases have been developed.** These synthetic greases have less than one tenth the evaporation losses of the earlier mineral oil greases, and have been found suitable for control bearing, electric motor bearing, and actuator operation over a temperature range of lower than $-67°$ F. to $+250°$ F. Ball and roller bearing lubrication is excellent at a maintained temperature of 250° F., and is even satisfactory for short periods at temperatures up to 300° F. Con-

*Former Specification AN-G-3a.
**Specification MIL-G-3278, formerly AN-G-25.

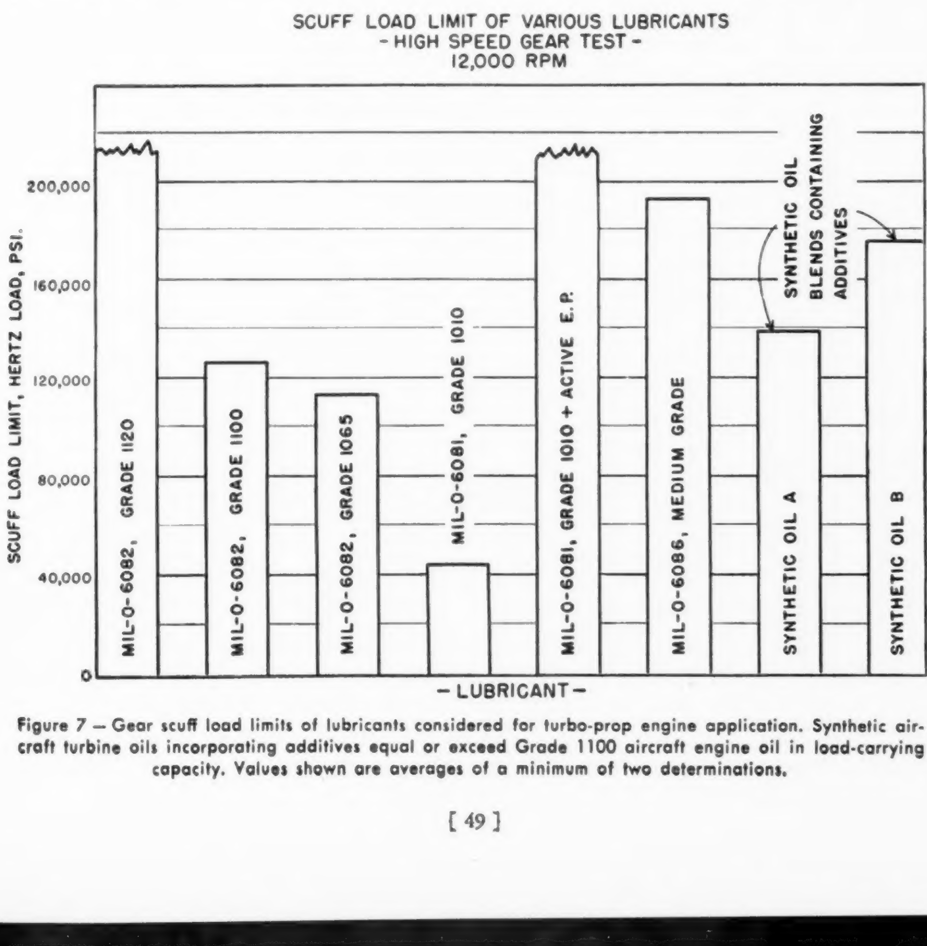


Figure 7 — Gear scuff load limits of lubricants considered for turbo-prop engine application. Synthetic aircraft turbine oils incorporating additives equal or exceed Grade 1100 aircraft engine oil in load-carrying capacity. Values shown are averages of a minimum of two determinations.

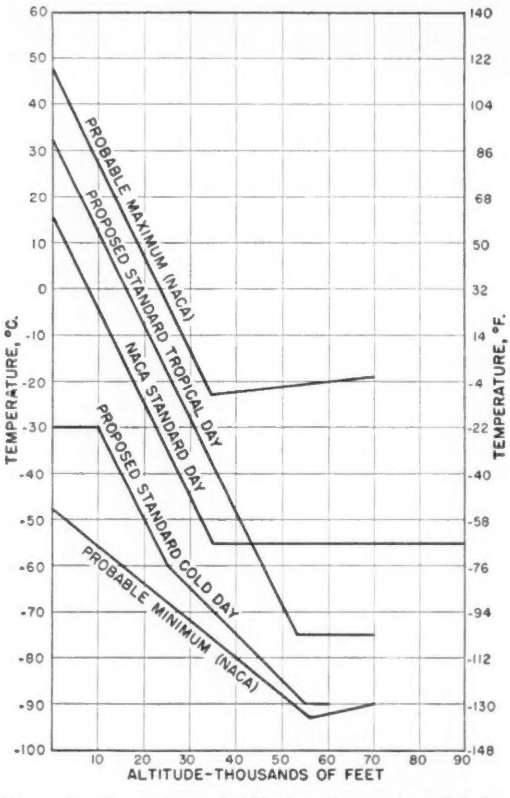


Figure 8 — Comparison of Altitude — Temperature Relationships of NACA Standard Day with Revised Concepts based on Upper-Air Research. Note that above 44,000 feet, temperatures for standard tropical day are much lower than the NACA tropopause of −67° F., and probable minimum values are even lower.

sequently, the wide temperature range synthetic greases are preferred for intermittently operated equipment exposed to both very low and moderately high temperatures. Such lubricants meet all or most of the grease lubrication requirements of aircraft operating in all climatic zones up to altitudes of 30-35,000 feet. They are also effective in instrument bearings and miniature precision bearings of all types.

At higher altitudes, however, chances are that exposed equipment will encounter outside temperatures as low as —100° F. At this temperature, even the normal synthetic greases may stiffen and cause excessive power or torque requirements. Thus a requirement has arisen for ultra-low temperature lubricants satisfactory for limited torque operation at −100° F. At least one product satisfying these requirements has been developed, with evaporation losses no greater than those of the synthetic greases developed for −67° F. A military specification has been issued to describe the new grease, MIL-L-7421, intended only for certain applications in very high altitude bombers, although it may be applied to exposed equipment in jet fighters and transports if service requirements develop. So far, the −100° F. greases have not been found equal to MIL-G-3278 greases in anti-friction bearing lubrication at high temperatures, further limiting their application to exposed equipment subjected only to ultra low and moderate temperatures, but not to high heat under continuous running.

General Purpose Greases

A single wide range grease, with mineral oil base, has been found suitable for many aircraft grease requirements. This type product is the one most generally used today for grease-lubricated points throughout light and civil aircraft, medium altitude transports, and low and medium altitude military craft.

The military specification for general purpose grease is MIL-L-7711*, developed for several types of accessories, propellers, wheel bearings, and pressure-gun points such as are found on retractable landing gears. Greases to this specification are partially water resistant, stand up under shear, and are good anti-friction bearing lubricants. They may be used at grease lubricated points in the control system and throughout the entire aircraft for temperatures down to −40° F., if torque is limited, to −67° F. with high starting torque, and for continuous operation at +250° F. General purpose grease has been used for grease lubricated components of pneumatic systems.

While the general purpose type of aircraft grease is an excellent wheel bearing lubricant in normal service, its limited water resistance may create a rusting problem in wheel bearings of aircraft in intermittent service or exposed to severe waterworking through faulty seals. Under such conditions, wide temperature range synthetic greases or high temperature greases are preferred by some operators, while others have obtained excellent service from selected soda-soap automotive wheel bearing lubricants. The latter have desirable water absorption and metal adhesion characteristics, preventing rust, and it has been found that the ample torque available for wheel rotation upon landing presents no obstacles to the lack of low temperature properties, at least in present medium altitude transports up to the DC-6 category.

High Temperature Greases

The bearings of electrical accessories such as generators, magnetos, and dynamotors often have high operating temperatures but are not exposed to severe low temperatures. Special high temperature aircraft greases have been developed for such applications. In qualifying under the applicable mili-

*Formerly AN-G-15.

tary specification, MIL-L-3545, products are required to lubricate a high speed bearing continuously for a minimum of 600 hours at 300° F.

The miniaturization trend, noted above, has increased the severity of the upper temperature range in which small electric motors must be satisfactorily lubricated. If both low and high temperature requirements must be met, MIL-G-3278 synthetic-base products are the preferred application, having the required low temperature properties and having been found satisfactory for short periods of operation up to 300° F. If continuous or ultra high temperatures are involved, the MIL-L-3545 greases have an edge, more pronounced above 275-300° F. High speed bearing performance of even the best present high temperature greases falls off rapidly above this range, Figure 9.

No completely satisfactory thixotropic lubricants have yet been found for the temperature range of 350 to 400 plus °F. This temperature range is becoming increasingly important in jet engine accessory and actuator control bearings, and is known to occur in guided missiles, where some of the pumps and motors, as well as control systems may require grease lubrication. Temperature rises on the skin surfaces of supersonic missiles have been reported as great as 360° F. above the outside temperature, as a result of ram air adiabatic temperature rise and skin friction. Accordingly, work is being done toward the development of grease-type lubricants to function above the range of present high temperature lubricants. Promising results have been reported for silicone-base greases;[7] other efforts are directed toward compounding synthetic oils with specially selected soap constituents, with which considerable improvement has already been shown over conventional greases.

EP and Graphite Greases

The loadings and conditions of operation of some grease-lubricated airframe components and accessories requires special greases with EP qualities or colloidal graphite to prevent metal-to-metal wear, galling, chattering or sticking.

The current EP grease is designed for use on aircraft gears and actuator screws and is described by MIL-G-7118. This grease is required to have the low temperature properties of the synthetic greases plus added EP for the functions noted. It replaces the former AN-G-10, an EP version of petroleum base low temperature grease, which has been widely used in screw jack actuators, highly loaded gears, and sliding mechanisms, but suffers from the same high temperature limitations as AN-G-3a greases.

Present graphite grease for aviation usage is a mixture of general purpose aircraft grease and 5% fine graphite, as described by MIL-G-7187. It is intended primarily for starter drives, but also is used on some types of sliding surfaces, actuators, and drive screws. The recommended temperature range is the same as that of the base grease, down to −65° F. with plenty of torque, otherwise −40° F. to +250° F.

LUBRICATING OILS AND HYDRAULIC FLUIDS

New developments in fluid lubricants for aircraft use since the subject was last presented in LUBRICATION* may be summarized by two trends:

1. Use of synthetic lubricants for special applications having a very wide temperature range or other restrictive requirements.

2. Development of non-flammable or less flammable hydraulic fluids, centering about synthetic or water-base fluids.

Special synthetic oils that have been used include very low viscosity, high V.I. instrument oils and a synthetic lubricant, Specification MIL-L-6387, for constant speed engine accessory drive mechanisms. In the latter case, it was found that light

*April, 1946.

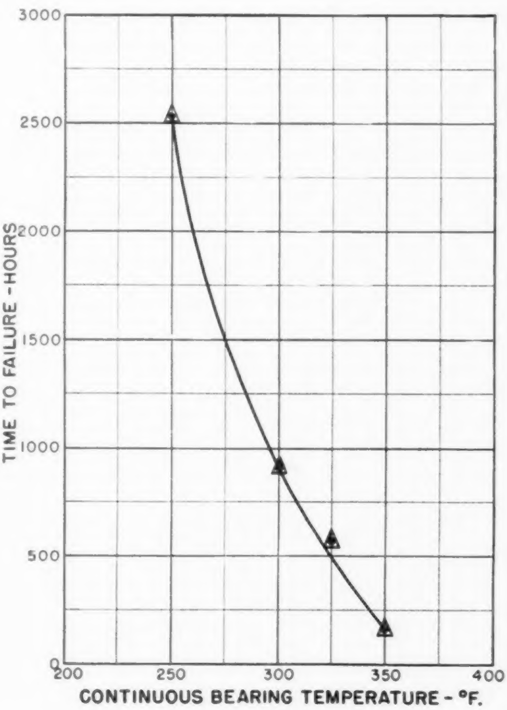


Figure 9 — Effect of Operating Temperature on Endurance Test of High Temperature Grease in High Speed Bearing Performance Machine. Severe effect of temperature emphasizes importance of keeping operating temperatures down and also need for improved high temperature lubricants.

mineral oils with the required low temperature properties were not adequate for lubrication and prevention of wear at higher temperatures, and also suffered from shear break-down. A special synthetic oil was developed under Air Force contract with excellent service results reported.

Pneumatic systems, using compressed air at up to 3000 psi, have replaced or supplemented hydraulic systems in some new aircraft, the chief advantage being weight. Compressors and some of the air motors are lubricated with oil. Jet engine oils, instrument oil, and aircraft gear oils are among the lubricants being used; however, again the low and high temperature extremes, as well as the fire hazard, have directed attention toward synthetic lubricants.

Work on non-flammable hydraulic fluids dates from before World War II, and was accelerated by a desire to decrease the vulnerability of military aircraft. Several promising types of materials have been developed, among them an ester-type product, and the water-base fluids preferred by the U. S. Navy Bureau of Aeronautics. Both types of products are being used in service, not without minor problems, and research by petroleum and chemical laboratories is continuing. Chief problems in the development of satisfactory fluids are compatibility with existing seals and rubber compounds, high and low temperature stability, corrosion, lubrication, toxicity, effect on aircraft materials, and high cost. For airline hydraulic fluid use, there is still a question as to the need for non-flammable fluid*, and some operators have indicated a preference for the less expensive MIL-O-5606 petroleum base fluids for which the hydraulic systems of most present aircraft were designed.

No clear pattern exists in lubrication of aircraft cabin superchargers except that compressors and drive units require oil lubrication. The type of oil recommended varies according to the design of different units, ranging from aircraft engine oil, through jet engine oils, to hydraulic fluids. SAE-10W and 20W motor oils are recommended in some drive units, the Heavy Duty type being preferred for greater oxidation resistance and also because such oils tend to have lower pour point and low temperature viscosity characteristics than regular motor oils. Foam resistance also is apt to be greater in the Heavy Duty oils, through added foaming protection. For lubrication of cabin superchargers in their current aircraft, one aircraft manufacturer recommends only the proprietary hydraulic fluid endorsed by them. It may be anticipated that if non-flammable hydraulic fluids come into general airline use there will be a move to realize full protection from such fluids by also using them in cabin superchargers, provided viscosity and lubrication properties are suitable.

Aviation Week, December 24, 1951, pages 39-40.

Perhaps the nearest product to a universal cabin supercharger lubricant for commercial use presently available is the special hydraulic fluid, Automatic Transmission Fluid Type A, developed for automatic transmissions and torque converters.* This type fluid appears to have the low temperature properties required in present commercial medium-altitude service, together with high V.I., and improved EP lubrication and oxidation characteristics over the motor oils. Such products, and supercharger lubricants in general, should be used only with the approval of the aircraft or supercharger manufacturer.

SUMMARY

An attempt has been made to present briefly the historical background of the aviation industry, with emphasis on the development of air transport. Recognition should be given to advances in other fields of aviation — military and civil — which have been equally as great during the first half-century of powered flight. Through constantly improved fuels and lubricants, the petroleum industry has contributed to the technical advancement and growth of all phases of aviation. A few of the more significant developments in fuels and lubricants have been presented in this review, with also a brief look ahead. Along with aerodynamic and propulsion studies, petroleum research promises that developments in the forthcoming period will equal or overshadow those of the past and present.

REFERENCES

1. "The Wright Brothers as Aeronautical Engineers," M. P. Baker, SAE Trans. Vol. 5, 1951, p. 1.
2. Aviation Gasoline Manufacture, M. Van Winkle, 1944, McGraw-Hill, New York, p. 10.
3. "Aircraft Engine Performance with 100-Octane Fuels," F. D. Klein, J. Aero. Sciences, March, 1935, p. 43-47.
4. "Aircraft Gas Turbine Fuels," H. A. Murray, Oil and Gas Journal, March 29, 1951, p. 218-9, 271.
5. "Jet Fuels — The Airline Viewpoint," J. T. Hendren and J. G. Borger, Pan-American World Airways, Inc., Esso Air World, September-October, 1951.
6. "The Earth's Atmosphere," H. E. Roberts, Douglas Aircraft Company, Aeronautical Eng. Rev., October, 1949, p. 18-31.
7. "Properties and Performance of Silicone Lubricants," G. Grant, III, and C. C. Currie, Dow-Corning Corp., Mechanical Engineering, April, 1951, p. 311-316.

"Development of Aircraft Engines and Aviation Fuels," R. Schlaifer and S. D. Heron, Andover Press 1950.

"The Air Force Looks on Synthetic Lubricants," B. Rubin and E. M. Glass, SAE Trans., April, 1950, Vol. 4, p. 287-296.

*LUBRICATION, November, 1949, November, 1950, November, 1951.

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